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雑誌名	The science reports of the Tohoku University. 7th series, Geography
巻	25
号	1
ページ	135-144
発行年	1975-06
URL	http://hdl.handle.net/10097/45004

Some Aspects of Floodplain and Alluvial Terraces in Tohoku District

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In his previous investigation made public in 1971 on the alluvial terraces (Holocene) and floodplains in the alluvial lowlands in the southeastern part of Aomori Pref., Japan, the author pointed out that there is a clear distinction recognized between the former and the latter in the mid-and downstreams in these alluvial lowlands. The present paper deals with a number of facts that the author has investigated about the alluvial terraces (Hollocene) and floodplains in the areas bordering some representative rivers in the Tohoku District. The large scale topographic maps (1/5000–1/2500) of the channels of each river and their vicinities and the hydrographical data were obtained by the courtesy of the Work Offices of Tohoku Regional Construction Bureaus, Ministry of Construction.

1 The Outline of the Rivers and their Alluvial Lowlands (Fig. 1)

There are some large basins along the upstream of river basins of the seven rivers investigated, except for the Iwaki River. When the characteristic of each river is considered chiefly in terms of its slopes and high water level discharges, the Tsugaru Plain through which the river runs is a. 60 km from south to north and a. 20 km from east to west, being considered to be a larger one in view of its magnitude. The average slopes of channel floors of the Iwaki River in the alluvial lowlands are: a. 1/2400 in the river reach 15 km away from the mouth; a. 1/1000, 15 to 45 km; a. 1/360, 45 to 57 km. The river channel makes a straight channel pattern in the first river reach nearest from the mouth. In the second river reach it makes a meandering channel pattern, where in the floodplains are found a variety of micro-fluvial forms as well as meander scrolls. In the third river reach the river channel makes a braided channel pattern. Near this channel are many ancient channels where meander wave length is longer than meander amplitude. The high water level discharges (H.W.L.Q.) of these three river reaches are 2100, 200, 900 m^3/sec respectively.

The Yoneshiro River which runs from east to west reaches the Noshiro Plain after running through the three basins, and empties into the Japan Sea. The

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Fig. 1 Location of study area
Ak: the Akita Plain, Fu: the Fukushima Basin, Ha: the Hachinohe Plain, Kk: the Kakuda Basin, Ko: the Kōriyama Basin, Kt: the Kitakami Basin, No: the Noshiro Plain, Sh: the Shōnai Plain, Sk: the Sukagawa Basin, Sn: the Sendai Plain, Tk: the Takanosu Basin, Tu: the Tsugaru Plain, Ym: the Yamagata Basin, Yn: the Yonezawa Basin, Yo: the Yokote Basin,
N–1: the Omono River narrow belt,
N–2: the Mogami River midstream narrow belt,
N–3: the Mogami River upstream narrow belt,
N–4: the Motomiya narrow belt.

areas investigated are the Noshiro Plain and the Takanosu Basin. The Noshiro Plain is comparatively a small plain which is a. 17 km from east to west and 3 km on the average from south to north, whereas the Takanosu Basin is a. 5 km shorter from east to west.

The average channel slopes and the high water level discharges (H.W.L.Q.) of the Yoneshiro River are:

The Noshiro Plain ......Channel slope 1/4800, H.W.L.Q. 6000m^3/sec.
The Takanosu Basin ......Channel slope 1/2000, H.W.L.Q. 4800m^3/sec.

In both of the lowlands are many ancient meandering channels and there exist many typical point bars along the present channels.

The average slope of the channel floors of the Omono River in the Akita Plain is a. 1/3700 and H.W.L.Q. in the river is 800 m^3/sec. The river channels no longer meander at present, but there are many ancient meandering channels observed near the river channels. The Yokote Basin is a. 15 km from east to west and a. 65 km from south to north. The majority of the river channels of the Omono River are situated in the western margin of the basin; that is, the trunk is in the outer edge of the alluvial fans formed by the branches of the river.

The river channels investigated in the basin are those that are 42 km in length. They are divided as follows:

I (0–16 km) II (16–34 km) III (34–42 km)

Slope	1/1300	1/820	1/500
H.W.L.Q.	7900 m^3/sec	5400 m^3/sec	4500 m^3/sec

The present river channels in the river reach I are meandering, whereas the river channels in the river reaches II and III form a braided stream with a large amount of sandbanks in the channels. But in the floodplains and the alluvial terraces (Holocene) near these channels there are many ancient channels in large curvature distributed.

The length of channel of the Mogami River is a. 27 km in the Shōnai Plain, and the river reaches are:

	0–11 km	11–27 km
Slope	1/2200	1/8900
H.W.L.Q.	7000 m^3/sec	7000 m^3/sec

The present river channels are of straight channel pattern, but there are many ancient meandering channels near the channels.

The Yamagata Basin is a. 40 km from south to north and a. 18 km from east to west. The river reaches of the Mogami River in the Yamagata Basin can be divided into three as those of the Omono River in the Yokote Basin.

	I (0–15 km)	**II** (15–38 km)	**III** (38–46 km)
Slope	1/1100	1/1300	1/840
H.W.L.Q.	4800 m^3/sec	4650 m^3/sec	1800 m^3/sec

The river channels in the river reaches **I** and **II** are well meandering, but **III** is of straight channel pattern. The Yonezawa Basin is situated away to the southwest of the Yamagata Basin. This basin is a. 40 km long and a. 5 km wide. The northern part of the basin is generally referred to as the Nagai Basin and the southern part, the Yonezawa Basin in a narrow sense. Accordingly, in the river reaches of both the Nagai Basin and the Yonezawa Basin there are many meandering channels and gentle slopes of channel floors. The average slope of channel floors in these basins is 1/700.

The river reaches in the lowlands down the Abukuma River in the Sendai Plain and the Kakuda Basin can be divided into the following two:

	I (0–11 km)	**II** (11–39 km)
Slope	1/5400	1/1800
H.W.L.Q.	6500 m^3/sec	5500 m^3/sec

The present river channels in **I** hardly meander, making a straight channel form. And near the channels there are observed some marks showing the existence of tributary in the past. The river channels in **II** also take a straight channel pattern, but near the channels there are a number of ancient meandering channels.

In the midstream and downstream of the Abukuma River are the Fukushima Basin, the Koriyama Basin and the Sukagawa Basin.

The Fukushima Basin	0–4 km,	4–11 km,	11–20 km,	20–28 km
Slope	1/500	1/1300	1/1800	1/1150
H.W.L.Q.	5500 m^3/sec	5100 m^3/sec	5100 m^3/sec	4600 m^3/sec
The Kōriyama Basin	0–4 km,	4–10 km	10–13 km,	13–15 km
Slope	1/820	1/2100	1/700	1/1300
H.W.L.Q.	3400 m^3/sec	3400 m^3/sec	2800 m/^{3}sec	2700 m^3/sec

There are rapid stream reaches in the two river reaches 4 km and 10 km away from the end of the basins. The river channels are meandering in the 4 to 10 km reaches, but in most other reaches are many river channels which take a straight channel pattern.

The Kitakami River is the largest river in the Tohoku District with its largest drainage area of 10,200 km^2 and its longest trunk of 247 km. The slope of channel floors in the downstream of this river is gentler than that of any other river mentioned so far; the average slope of channel floors is less than 1/8000 as far as 45 km from the river mouth. But in the river reachs in the downstream of the river there are less ancient meandering channels than in those reaches in the downstreams of other rivers. And most of the present river channels take a straight channel pattern. No alluvial terraces have been observed so far near the river channels in the downstream of the Kitakami River. The Kitakami Basin is a. 180 km from south to north and a. 20 km from east to west. Through the basin runs the Kitakami River from north to south, and the river reaches investigated are those a. 141 km away from the end of the Kitakami Basin. They are divided into five river reaches and the average slope of river floors and H.W.L. Q. of each river reach is as follows:

	I(0–27 km),	**II**(27–54 km),	**III**(54–75 km),	**IV**(75–105 km),	**V**(105–141 km)
Slope	1/2950	1/1500	1/800	1/1110	1/690
H.W.L.Q.	9000m^3/sec	9000 m^3/sec	6100 m^3/sec	4800 m^3/sec	3000 m^3/sec

Most of the present river channels, except in the river reaches **I**, **II** and **IV**, are not meandering in large curvature, but take a straight channel pattern.

About 90% of the drainage basin of the Mabechi River, which is 2640 km^2, is the mountain area, and the alluvial lowlands exist only in the Hachinohe and the small basins in the upstream of the plain. But the length of its trunk is greater than those of the Iwaki River, the Yoneshiro River and the Omono River. The average slope of river channel floors in the 0 to 21 km river reaches in the downstream is gentle, being 1/2440 with H.W.L.Q. 2700 m^3/sec. The present river channels are hardly meandering, but near the channels are many ancient meandering channels.

2 Some Aspects of the Floodplains and the Alluvial Terraces (Holocene)

(1) Plains (Downstream)

In the Hachinohe Plain, the alluvial lowlands less than 20 m in height occupy the majority of the plain. The alluvial lowlands are divided into the deltaic lowland less than 5 m high and the alluvial terrace (5–10 m). The deltaic lowland extends a. 5 km away from the shore, and its surface continues to the surface of the floodplain along the river channel. The surface of the alluvial terrace (5–10 m) is above the floodplain. The terrace scarp or the slope in relative height of 1–4 m divides the floodplain and the surface of the alluvial terraces.

The deposits of subsurface in the floodplains and the alluvial terraces along the channel about 5 km away from the river mouth are, roughly, as follows;

Floodplain (in depth): I (0–2 m) silt-clay bed alternating with fine-medium sand beds, or peaty silt and clay bed. II (2–3 m) silty sand bed. III (3–4 m) sand bed. IV (4–6 m) sand and gravel bed.

Alluvial Terrace: I (0–2 m) silt-clay beds alternating with fine-medium sand beds, or peaty silt and clay bed. II (2–4 m) silty sand bed. III (4–7 m) sand bed. IV (7 m+) silt with scattered shells.

The sand bed III in the deposits of the terrace truncated by the sand and gravel bed IV in the deposits of the floodplain, and filled by the sand and gravel bed.

The author collected the wood sample in the peaty silt of the floodplain bed, which was aged 325 ± 105 years B.P. (TH–029). In the alluvial lowland near the Oirase River abutting on the alluvial lowland of the Mabechi River, Matsui *et al.* (1969) obtained ^{14}C Age dated at 2140 ± 90 yrs. B.P. (Gak–1914) on the peat sample. Its peat bed lies at alternated beds silt and clay with peat in deposits of the alluvial terraces. Further, Ōike *et al.* (1972) obtained ^{14}C Age dated at 5280 ± 100 yrs. B.P. (GaK–3377) on the shell sample of IV bed in the Hachinohe Plain.

Recently, in the Kakuda Basin near the Abukuma River, Takeuchi *et al.* (1974) obtained the results of ^{14}C Age dated at 4930 ± 160 yrs. B.P. (GaK–4746) (lower bed) and 770 ± 140 yrs. B.P. (GaK–4765) (upper bed) on peat beds in the back swamp deposits of the Abukuma River.

Taking all the above-mentioned into consideration, the author defines the surface of the alluvial terraces (Holocene) as follows: it is a surface which lies near river channels abutting on the floodplain, and which is distinguished by terrace scarps or slopes a few meters in height, consisting of unconsolidated deposits.

The Noshiro Plain is of the same type as the Hachinohe Plain in that the alluvial lowlands are divided into two surfaces, upper and lower, as far as the vicinity of the river mouth. The upper surface is equal to the "Kemanai" surface named by Naitō (1966). The deposits in the Noshiro Plain are slightly different in thickness from those in the Hachinohe Plain, but the deposits in these two plains are the same in phase and sequence of deposition. The elevation of alluvial terrace surface ranges from 3.8 m to 4.3 m a.s.l. near the river mouth and 11 m to 12 m a.s.l. 18 km away from the river mouth, while the elevation of the floodplain surface is 1.2 to 2.4 m a.s.l. and 9.0–9.5 m a.s.l. respectively.

The scarps of the alluvial terraces are 2.8 m on the average in relative height, and the relative height between the floodplain and the average water level of the present river channels are 2.7 m on the average.

Except in the downstreams of the above-mentioned two rivers, the alluvial terraces of other rivers are not well-developed. In each plain the alluvial terraces begin to develop at the following distances measured from the river mouth along the present channels: The Abukuma R. a. 11 km, The Omono R. a. 11.5 km, The Mogami R. a. 15 km, The Iwaki R. a. 15 km.

The average difference in height between the floodplains and the alluvial terraces in each plain and all the catchment areas (c) and the catchment areas of the lowlands (cl) are as follows:

	Mabechi R.,	Yoneshiro R.,	Mogami R.,	Omono R.,	Iwaki R.
h(m)	3.9	2.8	2.8	2.4	2.1
c(km^2)	2640	4100	7040	4640	2540
cl(km^2)	170	450	1610	1350	750

This indicates the fact that the larger the lowlands are in relation to the magnitude of the river, and the larger the river is, the less the alluvial terraces in the plain have developed.

(2) Basin (Mid- and Upstream)

There is a surface 2.5 m in relative height above the floodplains along the Omono River in the Yokote Basin. The surface is entirely continuous from upstream to downstream in the basin. The subsurface deposits are composed of well-alternated beds of sand-silt and clay about 1.5–3 m in thickness, which overlie gravel and sand, or silty clay, without alternation. The alternated beds of silt-sand and silt-clay get thinner upward, and especially in the part 0.3–0.5 m in thickness near the earth surface, the beds are well alternated.

Shōji *et al.* (1974) obtained the results of ^{14}C Age on the subsurface deposits along the midstream in the Yokote Basin. The results are as follows:

	in depth (cm)	Sample	^{14}C Age
I	3–4	peat	4600 ± 110 yrs. B.P. (GaK–4037)
II	34–39	peat	12800 ± 210 yrs. B.P. (GaK–4038)

The author observed **II** peat distributing widely in the vicinity, but not **I** peat, which may be considered to lie in the above-mentioned small alternated beds. In any case there is no doubt that the geomorphological surface above the floodplains has developed into the surface of the river terraces in Holocene. The author regards, as he did before in the case of the plains, too, these terraces in the basins as the alluvial terraces (Holonece).

The average relative heights between the floodplains and the alluvial terraces, and between the floodplains and the average water level in the basins and in the narrow belt are as follows (the latter in parentheses):
The Yoneshiro R. – The Takanosu Basin 2.9 (2.4) m; The Omono R. – The Omono River narrow belt 3.6 (3.6)m, The Yokote Basin 2.5 (1.7) m; The Mogami R. – midstream narrow belt (from the Shonai Plain to the Yamagata Basin.) 3.0 (4.4) m, The Yamagata Basin 4.5 (3.8) m, upstream narrow belt (from the Yamagata Basin to the Yonezawa Basin.) 5.4 (7.4) m, The Yonezawa Basin 4.4 (2.8) m; The Abukuma R. – The Fukushima Basin 3.5 (3.2) m, The Motomiya narrow belt 2.0 (3.8) m, The Kōriyama Basin 2.8(2.5) m; The Kitakami R. – The Kitakami Basin 3.1 (3.9) m.

Generally, the relative height of the narrow belt is greater than that of the plains and the basins, except in the Motomiya narrow belt along the Abukuma River. The reason may be that in the narrow belt the change of water level is greater than in other river reaches such as basins.

The average relative height between the alluvial terraces and the floodplains in the Yokote Basin is as follows:
Downstream (0–16 km) a. 4 m; Midstream (16–35 km) 2–3 m; Upstream (35–45 km) 1–2 m
The results show that the height gets greater toward the downstream. The same tendency can be observed in the relative height between the floodplains and the average water level, and also in the case of other basins.

(3) The Average Slope of the Present Channel Floors, Floodplains and Alluvial Terraces (Holocene).

The average slopes of the present channel floors, floodplains and alluvial terraces of each reach along each river are as follows: The slope is shown in 0/100, c: slope of the present channel floor, f: slope of floodplain. t: slope of alluvial terrace.

Plain

The Iwaki R. (0–15 km) c 0.5, f 0.1, (15–45 km) c. 10, f 0.4, t 1.0. (45–53 km) c 7, f 2.1, t 2.0. The Mabechi R. (0–21 km) c 0.4, f 0.6, t 0.4. The Yoneshiro R. (0–28 km) c 0.2, f 0.5, t 0.4. The Omono R. (0–26 km) c 0.2, f 0.15. (26–29 km) c 0.2, f 0. 2, t 0.1. The Mogami R. (0–11 km) c 0.4, f 0.3. (11–27 km) c. 1.1, f 1.1, t 1.3. The Abukuma R. (0–11 km) c 0.1, f 0.1. (11–39 km) c. 0.5, f 0.7, t 0.7.

Narrow Belt and Basin

Only the examples of the Omono River Narrow Belt and Kitakami Basin are presented here because of the same tendency observed in other narrow belts and basins.

The Omono River narrow belt c 0.2, f 0.2, t 0.1. The Yokote Basin (0–16 km) c 0.7, f 0.5, t 0.4. (16–34 km) c 1.2, f 1.2, t 1.2. (34–42 km) c 2.0, f 2.0, t 2.0. The Kitakami Basin (0–27 km) c 0.3, f 0.94, t 0.11. (27–54 km) c 0.66, f 0.01, t 0.88. (54–75 km) c 1.20, f. 1.13, t 0.94. (75–105 km) c. 0.89, f 0.83, t 0.79. (105–141 km) c 1.45, f 1.47, f 1.47.

Along the river reaches in plains, the slopes of the present channels of the Yoneshiro and the Mabechi River are gentler than those of their floodplains and alluvial terraces, whereas the slopes of the present channels of the Mogami River and the Iwaki River are steep. Along the Abukuma River and the Omono River, there is little difference between the slope of the river channels and that of the floodplains and the alluvial terraces.

The slopes of the reaches in the narrow belt are gentler than those of the reaches in the upper and lower streams. When alluvial lowlands are wide enough in basins, it is natural that the slope of channel floors, floodplains and terraces should get steeper toward the upstream. But toward the downstream the slope of the present channel floors is steeper than that of floodplains and alluvial terraces. This tendency is observed in each river reach in the Yonezawa Basin and the Yamagata Basin. On the other hand, as in the case of the Kitakami Basin and the basins along the Abukuma River, the alluvial lowlands have not sufficiently developed for the magnitude of these rivers. In these basins there are one or two points where the slope changes (i.e. nickpoint) and all the reaches are divided into 2 or 3 "units" of reaches by the points which are again divided into 3 reaches as in the Yokote Basin.

Fig. 2 shows the relation in each reach, between the present high water level discharges and the average slopes of the alluvial terraces, floodplains and the present river channel floors. The line $S=0.06\ Q^{-0.44}$ in Fig. 3 is suggested by Leopold *et al.* (1964) to distinguish braided (above the line) from meandering (below the line) patterns. The above discharge (Q) is the bank-ful discharge, whereas the author's discharge is that of the high water level. Most points in the graph are distributed above the line, which means that the slope of each river channel, floodplain and alluvial terraces is far steeper. The method employed by the author in determining the slope might not be appropriate because the slope indicated in Fig. 2 is based on the distance of the present channel. The slopes of the floodplains and alluvial terraces presented in Fig. 3 are the ones based on the

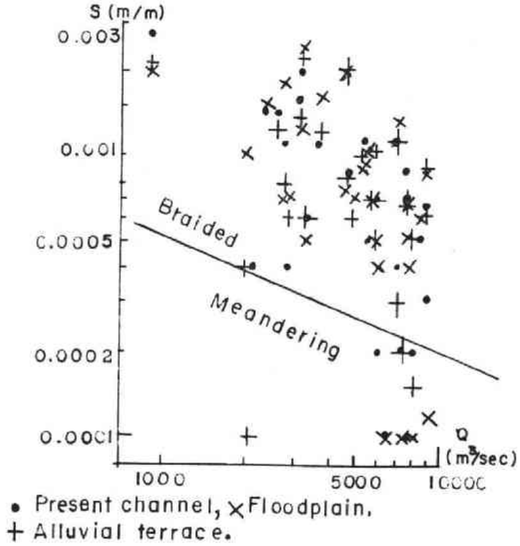

Fig. 2 The relation of slope (S) to discharge (Q)

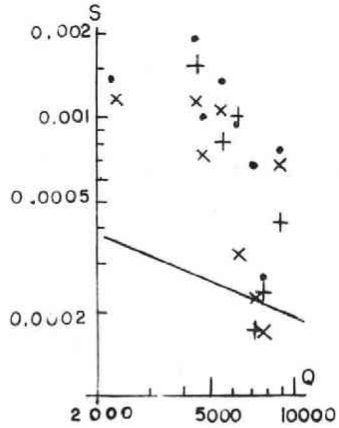

Fig. 3 The relation of slope (S) (is corrected) to discharge (Q)

distance of some clear ancient meander channels observed in part of the river reaches. But there are still many points distributing above the line. The high water level discharges must be decreased by about 1/10 and the slopes must get gentler by from 1/2 to 1/8 in order that supposed ancient river channels may be equal to the present microfeatures in Fig. 3. There is no possibility that the high water level discharges should be decreased by 1/10. Therefore it is to be suggested that the slope should get gentler at part of the reaches, that is, river should be temporarily dammed up at a reach or a narrow belt.

Summary

(1) The alluvial terraces (Holocene) in the alluvial lowlands along the representative rivers in the Tohoku District are developed, except in the downstream of the Kitakami River. Especially in the basins their development is continuous and sufficient.

(2) The alluvial terraces in the Noshiro Plain and the Hachinohe Plain begin to develop where the elevation of the plains attains the height of 4–6 m a.s.l., but in other wider plains they do so where the elevation attains 10–14 m a.s.l. The average relative height between alluvial terraces and the average water level in plains is 4.8 m. All these taken into consideration, it seems that surfaces of alluvial terraces (Holocene) are closely related to the high sealevel in Holocene.

And this is supported by some results of ^{14}C dating.

(3) In the end of basins, namely, along the downstream reaches, the relative height between the surface of alluvial terraces and the surface of floodplains greater, so is that between the surface of floodplains and the average water level. The slope of the surface of alluvial terraces is gentle in this reach and its surface smoothly continues to extend to the surface of alluvial terraces in narrow belts.

(4) The relation between the average slope and the high water level has proved quite different from what the author expected to grasp.

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